Compressed Air

DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

VOL. IV. NEW YORK, SEPTEMBER, 1899. No. 7

COMPRESSED AIR SANDING HOUSE, NORTHERN CENTRAL RAILROAD, SUNBURY, PA.

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A MONTHLY PUBLICATION DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

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Ten air cars are now operating on the Twenty-eighth and Twenty-ninth street lines of the Metropolitan Street Railway system in New York, and the experience derived from actual operation indicates their permanency, as they are fulfilling every claim that has been made for them.

The statements made by engineers in charge are corroborated by motormen, conductors and passengers, and a careful investigation by interviews with the same shows that a most satisfactory state of affairs exists.

A ride on the cars is a pleasant sensation. They run exceedingly smooth and outside of a slight sound from the exhaust there is practically no noise.

The passenger is cognizant of the independence of the car and the speed attained is sufficient for all requirements. The motormen on these cars are mostly men who have had experience in running electric cars, and they express no special preference to one more than the other.

During the months of May and June the air cars were placed in service on Twenty-third street, which is equipped with the underground trolley system. It was here that their speed was tested with the electric cars, and they proved their efficiency.

Under ordinary conditions, and with no incentive for the men employed to keep up any special speed, it was found that a car could be charged with air at the required pressure of 2000 pounds and the steam for reheating also injected within 4 minutes.

This process takes place at the terminal, which is opposite the Pennsylvania Railroad depot, at the foot of West 23d street, where the compressor and storage plant are located.

It would seem that, with everything equal in the matter of operating the system, there should be a decided showing in the economy of the air cars, for the reason that there is no expense corresponding to such items as the maintenance of overhead or underground trolley, which are said to be very great, and the cost of switchboards and the burning out of motors and sometimes the total demolition of cars.

Similar accounts come from Chicago, where the Hardie motor has found an important place on the North Clark street line. Recently one motor car pulled two trailers, and the three cars carried 300 persons at one time. The trip referred to was made in the evening, after the car had run from Elm street, where it was last charged, in the early morning, to the limits barn, a distance of over two miles, and had remained about eighteen hours in the barn. It completed the trip with 600 pounds pressure still on hand.

It is fully demonstrated that air cars are giving good satisfaction, and the many advantages they possess puts them in competition with the trolley systems.

Miscellaneous Applications of Compressed Air

Compressed Air and its distribution for power purposes in the city of Paris; how it is produced, its numerous applications and its cost.

By Mr. V. Popp.

History of the Enterprise.

The world renowned compressed air system for power purposes which is now in operation in Paris was started in a very small and modest way. Its point of departure was the installation of a small compressed air plant in 1879. This plant was installed in the basement of a dwelling house situated at No. 7 St. Anne street with a view of supplying compressed air to a small circuit for the operation of pneumatic clocks, and this was the first application of compressed air for this purpose. The machinery which was installed at that time consisted of two small steam actuated air compressors of 6 h.-p. each.

The receivers, pressure regulators, standard clock controlling all the pneumatic clocks and other apparatus consistent with the plant were installed on the ground floor; the main standard clock controlling all the pneumatic clocks on the compressed air circuit, which was at that time about three miles long, gave each pneumatic clock a *compressed air impulse* every minute moving the minute hand 1-60 of a revolution. In addition to these clocks, which were placed on the principal thoroughfares, and the results being so satisfactory, a large number of them were installed soon after the beginning of operations in a number of public buildings and private houses.

In 1898 the compressed air installations of the Popp System comprised the following:

1st.—One compressed air central plant of 8,000 h.-p., situated on the Quai de la Gare.

2d.—One central station for the operation of pneumatic clocks.

3d.—One main pipe line, having a total length of 138 miles, this pipe line being placed underground and located in a tunnel. Of these 138 miles of main pipe line 41 miles are operating the pneumatic clock service and 97 miles are for the supplying of compressed air for power purposes. In addition to the main pipe line there are over 20 miles of branches. These branches conduct the compressed air to 955 power consumers and to 1,637 establishments in which compressed air is used for the operation of pneumatic clocks.

4th.—Compressed air furnished to consumers operate 1,600 h.-p. of engines; is used in addition for 163 other purposes than power, and in addition there are 180 passenger and freight elevators all operated by means of compressed air.

5th.—The company owns and operates 7,000 pneumatic clocks. As will be seen, great progress has been made since the installation of the small plant in St. Anne street.

Qualities of Compressed Air.

The report of Mr. Humblot, General Inspector of Public Works in Paris, contains the following: "There is no reason why power could not be transmitted by means of compressed air, and the theoretical considerations on the subject have the tendency to give compressed air the preference above any other method of transmitting power. Compressed air is not a source of power, it is only a medium for the transportation of heat, which heat can be retransformed into power. Thus there is a great difference between this kind of power transmission and other methods such as the transmission and transportation of power by means of water or electricity. Water is nothing but a purely mechanical medium between the piston of the pump supplying same and the piston of the motor operated by same. It can be compared to a solid incompressible rod connecting two mechanical organs. Such manner of transmitting power presents many inconveniences and losses, and in no case can the power obtained by the motor operated by same be superior to the original power.

"Electricity is a form of energy, same as heat, and can be transformed into mechanical work, but here again the amount of power obtained at the further end of the line is always inferior to the power supplied at the starting point. As an electric conduit can receive nothing but electricity, the loss between starting point

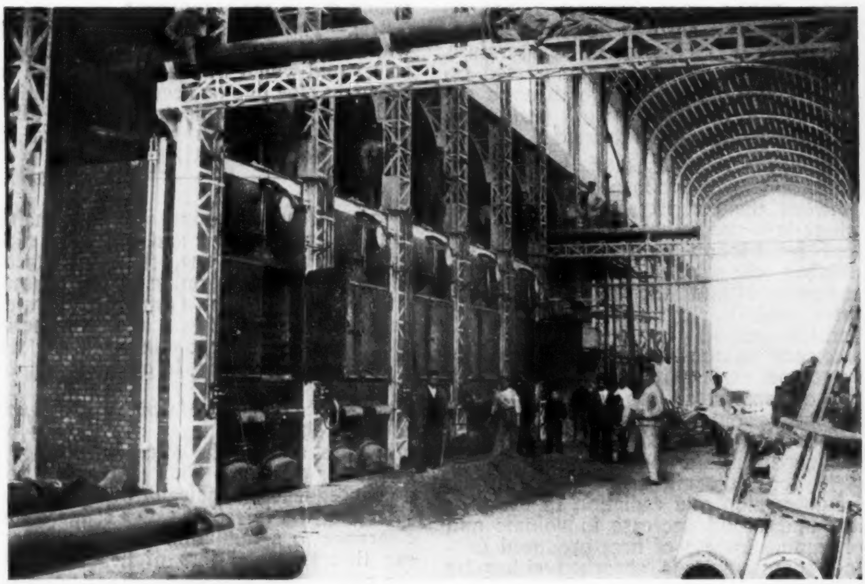
and final point must be made up by means of electricity, if such loss is made up. Now, in order to produce electric power heat has to be first produced; this heat transformed into mechanical work; mechanical work into electricity, and it is evident that this combination of transformations is inferior to a system which allows the making up of losses direct by the addition of heat, as can be done with compressed air. In order to fully understand the principles of distributing compressed air it is necessary to know the fundamental principles of the mechanical theory of heat and which are as follows:

"Any production of heat corresponds to the destruction of a power; any production of power corresponds to the absorption or destruction of a certain amount of heat.

"The unit of energy is the kilogrammetre, which represents the power necessary to elevate one kilogramme one metre in one second. The unit of heat is the calorie, and represents the necessary quantity of heat to elevate the temperature of 1 kilogramme of water 1° cent. This corresponds to the elevation of temperature of 4° cent. for 1 kilogramme of air. The absorption or suppression of one calorie corresponds always to 425 kilogrammetres of mechanical work produced; the absorption of 425 kilogrammetres of mechanical work corresponds always to the omission of one calorie.

"The above statement does not always exist in practice, and the role of the engineer consists in producing the above transformations from heat into work, and vice versa, with the least possible loss.

"Should this be obtainable in practice, the efficiency of compressed air apparatus would be 100 per cent.



Boiler Room of the Paris Plant.

"Example.—One kilogramme of coal represents practically 5,000 calories; with 900 grammes of coal a steam engine will produce practically one h.-p. during one hour, the one h.-p. being equal to 75 kilogrammetres. As the hour is equal to 3,600 seconds, we can say $\frac{75 \times 3,600}{425} = 635$ calories, and then $\frac{635}{5,000 \times .9} = 14$ per cent.

"It is well known that 800 calories are

lost through the smokestack; that 600 calories are absorbed in condensation, and that the balance of the loss comes from radiation and absorption in general. Thus we are in a position to say that for the present, and until better apparatus for the generation of heat and steam are produced, the steam engine in its present condition has reached an almost perfect stage; but, notwithstanding its low effectiveness of 14 per cent., it is at present the only method of obtaining primary power. For air, however, we are confronted with a different problem. Air must be considered only as a reservoir for heat and a vehicle capable of transporting same. When air is compressed it forms a resistance, it absorbs power, and consequently it increases in temperature. When this air, after being compressed, regains atmospheric pressure through expansion and mechanical work performed, its temperature will be decreased.

"Suppose that air, after being compressed, would not lose any of its heat between the compressor and the place where it is used; that there would be no loss by friction or leakage; that the number of calories absorbed by the compressor and the number of calories lost during the work of expansion would be equal, then the efficiency of the air compressor would be 100 per cent. This does not take friction of compressor into consideration. It cannot be obtained in practice, as we do not allow the air to absorb all the heat produced during compression. If this were done, the air would lose its heat by absorption and radiation in the pipe line and would decrease in volume and pressure. Excess of heat produced during compression is absorbed either by water injection or by water jacket circulation during the process of compression, and each calorie absorbed by the water corresponds to a loss of 425 kilogrammetres in the receiver, or an equivalent loss in weight of compressed air.

"According to Pernolet, the amount of heat produced by compression and which should be absorbed during the process of compression is as follows:

For two atmospheres—14 calories.
For three atmospheres—23 calories.
For four atmospheres—29 calories.
For five atmospheres—34 calories.
For six atmospheres—38 calories.
For seven atmospheres—41 calories.

"Suppose that we use water at 15 degrees cent., and, furthermore, that the water would be discharged at 30° cent., each kilogramme of water would absorb 15 calories, and for a pressure of seven atmospheres we would require 2.7 kilogrammes of water per kilogramme of air admitted to air cylinder.

"It will be seen later that one h.-p. being able to handle eleven kilogrammes of air, the practice and theory will agree. Thus, per nominal h.-p. of a steam engine, the amount of water required will be $2.7 \times 11 \times 15 = 445$ calories.

"In addition to the above loss of power during compression, there are several others which are secondary:

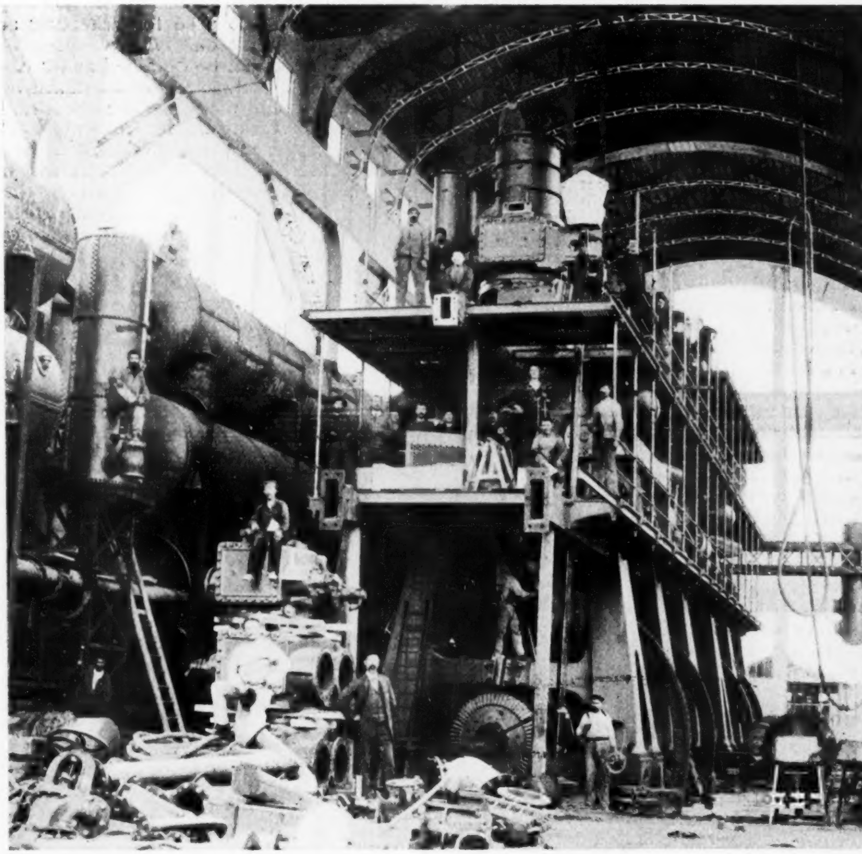
"1st.—The contraction of the air, which will be discharged at 30° cent. into the receiver and which will cool to 15° cent. in the main pipe line on account of radiation and absorption. This loss for 11 kilogrammes of air per h.-p. will be equal to

$$\frac{11 \times (30^\circ - 15^\circ)}{4} = 41 \text{ calories.}$$

"2d.—A certain amount of vapor remains in the compressed air and is carried with same into the pipe line. The quantity of vapor is hard to determine. We can, however, count on about 10 grammes of water per cubic metre of air at atmospheric pressure; this corresponding to about 100 grammes per h.-p., or, in other words, 61 calories.

"3d.—The quantity of water required for cooling, either by means of injection or otherwise, reduces the volume or capacity of the air cylinder. This is, however, of no consequence, principally when we consider that the injection water reduces the clearance to a minimum. Thus, we can say that the total loss of heat between the compressor and the terminal point of pipe line amounts to $445 + 41 + 61 = 547$ calories. As we have used 635 calories to compress the air and have a loss of 547 calories during compression, etc., we can deliver only 88 calories to the engine or other apparatus at the further end of the pipe line. We know, however, that compressed air is a valuable receptacle for calories and that it will give them up when required to produce mechanical work, we can add calories to produce compressed air, and these calories will be given up and transformed into mechanical power or energy in addition to the original calories stored in the compressed air. Practice has proved that compressed

air will lose 65° cent. for a reduction in pressure of six atmospheres. Theory will bring the figures to 90° cent. We have thus for each kilogramme of air a reserve of $\frac{15 + 65}{4} = 20$ calories, and as each h.-p. handles 11 kilogrammes of air the number of calories stored would be 220. Adding to this the 88 calories added by the work of compression, we find that 1 h.p. of compressed air will amount to 308 calories at end of pipe line; thus, using 635 calories to do the work of compression, and obtaining 308 calories in work, the practical percentage of efficiency of the air compressor would be 48.6 per cent. If we consider, however, that the difference between the indicated and nominal h.-p. amounts generally to about 18 per cent., this loss being due to leakage, friction, dead-load of the engine, etc., for the steam engine itself, and that the air leakages in the air pipe line amount to about 5 per cent., we can only count on a practical efficiency of 37 per cent.



AIR COMPRESSORS AND AIR STORAGE RESERVOIRS.

"This result being obtained without taking reheating into consideration.

"Practical tests made by a commission appointed by the Ministry of War have

demonstrated that four 450 h.-p. air compressors have absorbed 38,000 kilogrammes of free air and have produced 16,000 kilogrammes of compressed air. The tests being made on short pipe lines without any leakages whatever, it will be seen that the practice agrees nearly with the theory, the effectiveness of the tests giving a result of 42 per cent., while the theory above mentioned should have called upon an effectiveness of 48.6 per cent.

"The difference between theory and practice is thus only 6 per cent. As air is a proper receptacle for the absorption and storage of calories at any stage during the compression before being used for power purposes, it is a very important subject to study as to how a certain number of calories can be given to the air after compression in order to make up for all the loss due to cooling, leakage, etc. There is no limit to the number of calories which can be added to the air except that a too high elevation of temperature wants to be avoided, as it would prove either inconvenient or dangerous. We have seen above that there are only 88 calories out of 635 available during expansion at the terminal point. Thus, in order to obtain 100 per cent. of power we ought to restitute 547 calories per indicated h.-p. Should we figure on nominal h.-p. we should add about 20 per cent.

"This would bring the total number of calories required per nominal h.-p. to 762. Now, having seen that 11 kilogrammes of compressed air will store 88 calories, or in other words 8 calories per kilogramme, let us see in practice how many calories we can add to each kilogramme of compressed air by means of heat either in one, two or three stages before and during the work of expansion. It is easy while expanding to reduce the temperature of air 150° cent. (with two expansions, a decrease of 300° cent.). This decrease in temperature can be obtained while expanding the air in two cylinders, increasing its temperature 150° before letting it enter each cylinder. The total loss of temperature being 300° it represents a loss of 75 calories per kilogramme of air, which, added to the 8 calories which the air was ready to give up ordinarily, the total number of calories absorbed will be 83.

"We have said above that one kilogramme of coal represents 5,000 calories, and that to consume this coal we have to lose 16 cubic metres of air at 400° in the smokestack, this being equivalent to 1,600 calories, the loss will be 32%. In order to obtain the 5,000 calories with one kilogramme of coal we will have to add 246/1000 kilogramme of coal. Theory has demonstrated that the efficiency without reheating amounted to 37%, thus it will be seen that for 1/10 of a kilogramme of coal consumed at the central power plant and 246/1000 used for reheating at the terminal point one effective h.-p. of compressed air can be obtained and a decrease of temperature at 300° cent. will be effected. Should the increase in heat furnished by reheating amount to only 150° cent., a larger amount of coal in reheating would be necessary. Tests which have been made confirm positively the above statement, and it is a remarkable proof that the hot air motor is a perfect thermic engine, where theory and practice differ the least.

"It is well known by all technical engineers that hot air engines are machines which show the best results theoretically, and that if these machines are not used in greater number it is on account of their complications in construction. All the hot air engines are based on the following principle, which is to introduce a certain number of calories under the piston of the engine and then transform the heat into mechanical work by either of the two following processes:

"1st. The compression of air in the machine itself in order to expand same later on.

"2d. Direct expansion of heated air, using the power obtained direct on the crank.

"The above operations are explained by the following formula: The calories which are transformed into mechanical work are equal to the work of compressing plus the work on the crank. The sum of these two energies, i. e., compression and power, which can be used, require a great number of calories, or, in other words, a great amount of energy on the piston of the engine; this piston, presenting only a small surface, is subject to great strains and also to deterioration on account of the great amount of heat prevalent.

"Thus it will be seen that the ideal is to compress the air in a different machine than the one which is used for producing the power, and for this purpose central

compressed air power plants prove to be the best adapted where compressed air power can be obtained and produced cheaply, and then the consumer needs only to attend to the reheating, which amounts to very little regarding expense and attendance.

"To obtain a nominal horse-power at the end of the pipe line we have to use 1.50 kilogramme of coal, of which 900 grammes are used at the central station and 250 grammes at the terminal point for reheating. This gives us an efficiency of 78% and is under all conditions superior to the best results obtained by electrical power transmission.

"4th. The installation of a compressed air central power plant for distribution comprises:

"1st. One central power plant, comprising air compressors, boilers or other

PLACE DE LA REPUBLIQUE, PARIS, SHOWING THE COMPRESSED AIR MAIN PIPE LINE.

power medium, receivers, pressure regulators, etc.

"2d. A complete endless main pipe line starting from the central power station and returning to same. From this air pipe line a certain number of branch pipes run for the distribution of com-

pressed air to the consumers; these branches furnished with automatic water traps in order to eliminate the condensed water.

"3d. Air meters placed at every outlet for measuring the amount of air used by every consumer, these meters varying to suit pipes from $\frac{1}{4}$ inch to 3 inches in diameter.

"4th. Apparatus for charging the receivers of compressed air cars or tramways, together with reheaters and all appurtenances connected with same."

Central Power Plant (Quai de la Gare), Established in 1891.

This is the most important central power plant not only in Paris, but in the whole world. The plant is installed and built of such size as to have an ultimate capacity of 24,000 h.-p. The outlay is arranged for the installation of three rows of air compressors, each row amounting to 8,000 h.-p. and comprising four 2,000 h.-p. air compressors; thus the complete installation comprises twelve 2,000 h.-p. air compressors.

The first row of 8,000 h.-p., which has been in operation since 1891, consists of four 2,000 h.p. air compressors of the triple expansion Corliss type for the steam end, the weight of these four machines being 1,800,000 kilos, practically 4,000,000 lbs.

Each of the low pressure steam cylinders weighs 30,000 kilogrammes (66,000 lbs.).

The boilers are of the water tube type furnished with economizers, five for each compressor, thus making a total of twenty.

The four compressors are fitted with positive air inlet and outlet and are of the three-cylinder type; two low pressure cylinders of same size fitted with intermediate receivers and intercoolers and one high pressure cylinder. That means the air compression is done in two stages. In addition to the above, part of the cooling is done during the period of compression by means of water injection in the cylinders.

The compressors are of the tandem vertical type, with three cranks setting at 120°, the steam cylinders being placed directly below the air cylinders.

The total height of each air compressor is $12\frac{1}{2}$ meters (40 feet).

The steam ends of the compressors are of the triple expansion type and are controlled for the low and intermediate cylinders by means of variable cut-off Corliss valves, with trip motion, while the high pressure cylinder, which is fitted with the same kind of valves, is controlled by an automatic combined air pressure and speed governor in addition to a quick acting variable hand governor; this in order to stop the racing or running away of any air compressor and to control its speed and output at a steady working pressure of 8 kilogrammes (i. e., 120 lbs.).

These different methods of governing and controlling speed and pressure, and which are each independent of the other, act all on the steam distribution of the high pressure cylinder.

The valve motion for the air cylinders is actuated through a system of spur gears placed on the main shaft; each compressor is fitted with two heavy flywheels and the shafts of the four engines which are placed in line are connected together with clutch couplings, thus allowing them all to work in unison. The four engines are besides rigidly tied together by means of heavy cast iron bed plates, thus insuring perfect alignment, the upper ends of frames being also tied together with heavy tie rods.

Access is given to all parts of the machines through four staircases and platforms extending the full length and on both sides of the four compressors.

The condensers, air pumps and water pumps are placed in pits next to the engines, these pits being 12 feet deep and reached by means of wrought iron stairs. Each compressor has its own condenser, air pump and water pump, the pumps being actuated directly from the crosshead of the high pressure cylinder through a beam controlled by same. The air valves of the two low pressure cylinders are of the positive inlet type and are fitted with rubber lined seats; the outlet valves are also of the same type, and it has been found that for low pressure cylinders these valves give very good results and dispense with shocks and jumping.

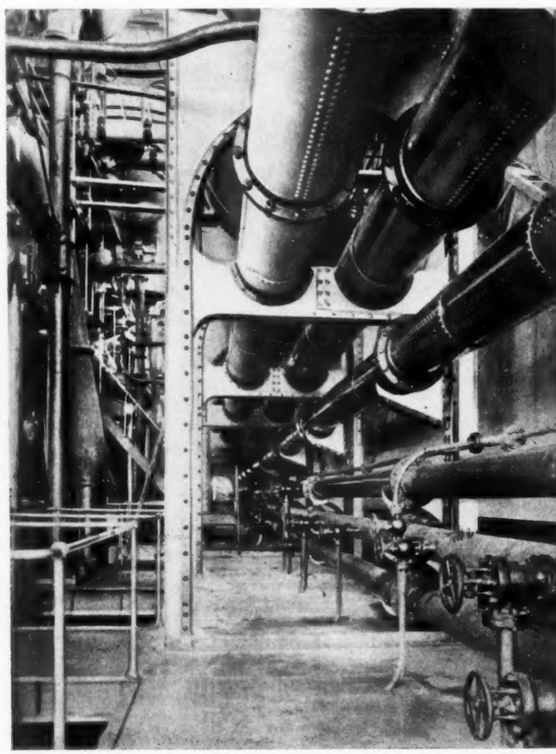
The two low pressure air cylinders are supplied with air direct from the atmosphere, discharging same into the combined receiver and intercoolers, which are placed on heavy cast iron columns; these receivers supply the air to the high pressure cylinder, where it completes its

compression and is discharged into the terminal receivers.

In order to insure the best results it has been decided to admit the air for supplying the two low pressure cylinders direct from the atmosphere and passing through small longitudinal openings whereby this air will give up part of its heat and moisture.

Direct steam actuated flywheel pumps, entirely independent of the air compressors, furnish the injection and jacket cooling water for the compressors. In addition, these pumps furnish water for cooling the compressed air in the intercoolers between high and low pressure cylinders and in the high pressure receivers.

The drawings and sketches accompanying this article will give the reader a fair idea of the general arrangement of the plant and a conception of the provision made for future increase. The engines have been built for extra heavy duty and are amply strong in all their parts to develop much more power than required. All working parts, such as piston rods, crank pins, crosshead pins, etc., are made of hard crucible steel and removable. Main bearings, crank and crosshead pin bearings, valve rod pin bearings, etc., are fitted with adjustable, removable bronze quarter boxes.



UNDERGROUND PIPES OF THE PARIS PLANT.

Up to this date, after eight years of steady work, both day and night, it has not been found necessary to renew any of the working parts of any of the air compressors except the rescraping and

regular readjusting incidental to general wear and tear.

All the engines run at a regular speed of 60 revolutions per minutes, but the combined air and steam governors allow this speed to be increased to 72 revolutions if required.

The amount of air handled per hour by the four machines now in operation (8,000 h.p.), and which is compressed to 8 kilogrammes per square centimetre (i. e., 120 lbs. per square inch) amounts to 70,000 cubic metres (220,000 cubic feet) per minute. The above is based on a temperature of 60° F. and a barometric pressure of 29 inches.

Each of the 2,000 h.-p. air compressors delivers its supply of compressed air at 8 atmospheres into two high pressure air receivers of 30 cubic metres capacity (i. e., 1,000 cubic feet each), from which it is distributed to the central main pipe line of 500 milimetres diameter (i. e., 20 inches diameter).

The boilers are of the water tube type manufactured by the Babcock & Wilcox Company, tested at 250 lbs. to the square inch, and furnish steam to the engines at 150 lbs. pressure. Each set of boilers is furnished with a steam reheater controlled in such a manner as to allow the steam from the boilers to pass through or around same. All steam pipes are installed in duplicates, thus allowing any engine or boiler to be put in or out of commission and to allow the cutting out of either of the main steam pipe lines in case of accident without interfering in any way with the operation of the plant.

Boilers to the number of 20 (i. e., 5 for each engine) are as follows:

Number of vertical sections for each boiler	12
Number of tubes per section	9
Number of tubes per boiler	108
Number of tubes—5.4 metres—equal	18 ft.
Diameter of tubes	4 in.
Heating surface for each boiler, 182 sq. metres, equal about	2,000 sq. ft.
Heating surface of economizers for the complete battery of boilers—500 sq. metres—equal	6,000 sq. ft.

Engines and air compressors are as follows:

Nominal h. p. of each engine	2,000 h. p.
Number of revolutions per minute	60
Pressure of compressed air in receivers, 8 kilogrammes	120 lbs.
Boiler pressure per sq. in., 12 atmospheres	180 lbs.
Diameter of high-pressure steam cylinder	36 in.
Diameter of intermediate steam cylinder	50 in.
Diameter of low-pressure steam cylinder	80 in.
Diameter of the two low-pressure air cylinders	44 in.
Diameter of high-pressure air cylinder	34 in.
Stroke of all the pistons	56 in.
Diameter of fly-wheels	18 ft.
Diameter of air pump	40 in.
Stroke of air pump	24 in.
Diameters of intercoolers and receivers	66 in.
Length of intercoolers	36 ft.

(*Continued.*)

Compressed Air in England.

This is a subject which has, during the past few years, been creating more genuine interest than some of the later discovered motive forces.

It used to be said that we know but little of the possibilities of electricity, and one hears the same now being said concerning compressed air, but we are expecting something from it—something startling, on the lines of liquid air. What a triumph for air—compressed or liquid—if it could solve the perpetual motion problem, with surplus power to spare. We are looking to you in America for these new developments. It would be doubly startling if they came from any other country, as it is a common saying here, that all things new and wonderful must come from America, so consequently your reputation is more or less at stake in this matter.

We, throughout Europe, are no doubt a long way behind you in the economical compression of air and the application of the same, due to a variety of causes, the chief of which is the air compressing manufacturer; who, instead of trying to construct his compressor on more economical lines and reduce to a minimum the loss of power between the steam and the air cylinders, seems to have accepted a certain low standard of efficiency, and no serious attempt has been made to improve upon it; it having been taken, that a great loss is inevitable, and that compressed air is only used when it is absolutely necessary, such as in mining operations, tunnel driving and other dark corners, where other motive forces are not practical; but happily this idea is fast dying out, owing largely to the publicity compressed air has attained during the last year or so, and the fact is being largely accepted that compressed air is not only useful in dark confined spaces,

but in the open daylight as well, competing alongside of steam and electricity and in many cases where steam is practicable, air is found more economical in its application. It speaks volumes for it, that in every case where it has been installed, for open quarry work, etc., for operating rock drills, cranes and other motors, the users are strong in its praise, and would not again go back to steam. Unfortunately compressed air in the past has been judged only by the loss of power between the steam and air cylinders, and the great convenience and saving in application has been overlooked. However, the time is rapidly approaching when compressed air will be recognized at its full value, and given its proper place. By that time it will be found that there are two kinds of air compressors—the good and the bad; the latter, dear at any price. If the public in the past had only purchased from well-known and tried manufacturers of this class of machinery the results would have been quite different.

One reason for our engineers being so long in adopting pneumatic appliances has been the difficulty of getting a satisfactory air compressor; and in many cases pneumatic tools have been tried and condemned, when it was entirely the fault of the compressor in not giving sufficient pressure, and being otherwise unsatisfactory.

There is no class of engine made in this country on so many different designs in attempting to accomplish the same purpose as the air compressor, and in the majority of cases the fatal mistake is made of not properly proportioning the fly-wheel. It is the apparent simplicity of the air compressor which has tempted many old established engineering firms to take up its manufacture as a kind of side issue, which needed but little attention; but many soon discovered, to their cost, that they had made a mistake, and that to design and manufacture a successful air compressor was no simple matter, but one which required years of study. As an instance, to show the difference between a good air compressor and a bad one, I might give a few details of two I saw a short time ago. One was constructed by a well-known and noted air compressor company and the other by a well-known firm of engineers, who had never before built an air compressor. The dimensions of the latter compressor are as follows: Steam cylinder 12-in. diam., air cylinder 12-in. x 15-in. stroke. This engine running at its maximum speed could not supply air above 20 lbs. pressure per square inch, for keeping one 3-in. cylinder by 5½-in. stroke rock drill at work, through a large pipe, distant only a few hundred yards. The other compressor, with dimensions as follows: —12-in. steam cylinder and 12-in. air cylinder by 14-in. stroke, and running at about two-thirds of its speed, was able to maintain 60 lbs. pressure per square inch, with two 3-in. cylinder drills constantly at work, through similar size pipe and under the same conditions. Of course this is an extreme case, the first compressor being a badly designed one and the necessity for reducing clearance spaces in the air cylinder having been ignored by the builder.

I might cite one more instance of some of the bad designs on the market: this time a belt compressor, constructed by quite a different firm, but proving equally unsatisfactory. The main driving pulleys for operating this compressor are about 4 feet in diameter; the fly-wheel pulleys on compressor are about 2 feet 6 inches in diameter (and very light in construction); the air cylinder is 16-in. diameter by 18-in. stroke, and running at a speed of about 75 revolutions per minute. With this compressor it is found quite impossible to raise more than 20 lbs. pressure per square inch; in fact this result can only be accomplished with difficulty, and abnormal wear and tear on the belts, owing to their lashing.

In larger size compressors we find much better design, construction and workmanship than is found in the small sizes. This is owing to the greater demand for big compressors for Colliery work, etc., the makers having gained more experience; but that experience has only led them to proportion their compressor a little better, and make it more of a mechanical job. (There is, however, much yet to be desired in this line). The inlet valves, which are the weak point in all our compressors, seem to have undergone but little improvement during the past twenty years. Better material is now being used, and consequently the danger of the engine being wrecked by valves breaking and falling into the cylinder is much lessened. However, even

now, it is not found safe to run at more than about 300 feet piston speed per minute, as anything faster would hammer up the valves, which would then become leaky and dangerous. This is a serious drawback, as otherwise the engine would be capable of running double the piston speed, which would naturally increase the capacity of the air compressor. These remarks, of course, apply to compressors with 5 to 6 feet stroke and above 18-in. diam. cylinder, which are practically the only type made in this country.

It also not infrequently happens that the compressor manufacturer is not sufficiently informed on the subject to know what size air pipes to advise or what kind of oil to use in the air cylinder. Consequently, in the first case, too small air mains are often put down over long distance, with the natural result of causing too much friction, and in the latter case, the air valves become clogged up and after a short existence the air compressor is a complete wreck.

Compressed air as applied to street cars seems to be having but little attention and development on this side; and it seems that the conditions are most favorable, as there is considerable opposition on the part of the public to having the streets disfigured with electric wires. However, all the chief cities have, or are about startings the overhead trolley system, but any enterprising firm who could put some favorable facts and reliable data before some of the corporations contemplating the adoption of mechanical power for street car service would no doubt have unprejudiced consideration, and a successful installation in any important city would be followed by the universal adoption of compressed air. With the exception of London the compressor power station could be so placed as to be within 3 to 5 miles of the terminus of the tram lines.

Take Glasgow (a very large city), and the power stations need not be more than 3 miles from the terminus.

Some Convenient Devices in a Railroad Yard.

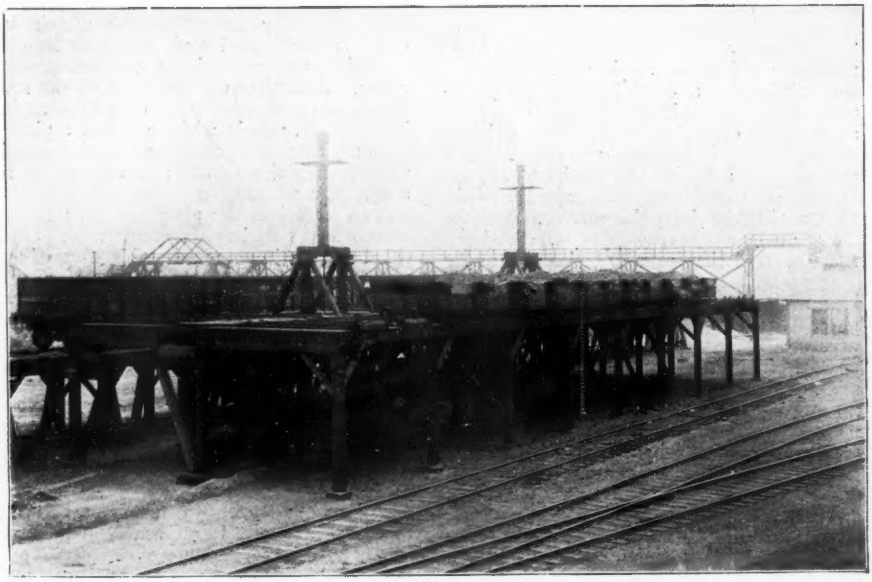
The three accompanying engravings show how compressed air is utilized in the yard of the Northern Central Railroad at Sunbury, Pa.

The cover shows that the sand house has to the right a post carrying a pipe, on the end of which is a short length of hose, which is dropped into the sand box opening. The building contains four sand dryers, arranged so that as the sand passes through the dryers it drops over a screen and into a large hopper, from which it is finally fed into a receptacle so arranged that the opening for the latter can be closed, air pressure put in and sand blown from this receptacle to the pipe and to the locomotive sand box.

View No. 2 is of the ash hoist and shows the same arranged for two ashpits with track on which cars may stand to be loaded with ashes between the two pits. The ashes are drawn from the ash pan, and the cinders from the smoke box, directly into a bucket, which can be moved lengthwise of the pit on a track, which is laid at the bottom. In this way they can be located conveniently under the locomotives and then moved under the frame and lifted by the hoist, which can also be made to traverse across the frame and dump the ashes into the cars.

View No. 3 shows a coal wharf at Sunbury, operated by compressed air. The cars containing coal are brought up on the low trestle at the back, where the coal is dumped from the hopper cars into coal dumps, which are moved longitudinally under the coal trestle and brought to a central point after being loaded where they are turned, weighed and brought to one of the two hoists shown, elevated to the platform and run on a transfer car, which moves the whole length of the wharf and deposits the loaded car at any track, and also removes the empty cars in the same way, but in the reverse direction. The transfer table is also operated by compressed air, the same being done by a small air motor.

View No. 2, Ash Hoist.



View No. 3, Coal Wharf.

Pneumatic Propulsion.

The facilities which the atmosphere offers as a propelling agent, and the readiness with which it lends itself to the purposes of locomotion, have for many years past caused a considerable amount of attention to be given to the utilisation of its mechanical properties for facilitating human intercourse. At no time, perhaps, was inventive talent more earnestly and more widely engaged in connection with pneumatic propulsion than in the early days of railways, when the advantages which the atmosphere theoretically offers in that connection were seriously pitted against those presented by steam. Prior to the advent of steam-worked railways in 1830, in which year the Liverpool and Manchester line was opened, inventors were hard at work in their endeavors to perfect the atmospheric system of railways, as it was then called, and a stimulus was given to their labors by the unfortunate death of Mr. Huskisson—the first railway victim—upon that occasion. One example of the prior application of the atmospheric principle to the propulsion of railway trains was that by Mr. John Vallance, of Brighton, in 1827, whose experiments were described in The Engineer of May 19th, under the heading of "A Singular Railway Experiment." It may prove interesting if we supplement that notice by a brief history of pneumatic propulsion, in which question such an amount of active interest was evinced during what is known as the railway mania, that a Select Committee of the House of Commons was appointed in 1845 to inquire into the matter. Let us, then, as Lord Jeffrey puts it, call back the departed life for a transitory glow.

It is now nearly two centuries and a half since Papin, in the year 1654, suggested the employment of atmospheric pressure against a vacuum as a motive power. The suggestion, however, does not appear to have been acted upon, nor the principle applied to any practical purpose until it was embodied in Newcomen's engine, which, of course, was not for purposes of locomotion. That application was left for later times to develop; and, according to the British and Foreign Review of April, 1844, the idea of applying atmospheric power for the propulsion of land carriages first occurred in a definite form in 1805 to Mr. Taylor, of Manchester, the inventor of the first power loom. Although that gentleman conceived the idea, he does not appear to have possessed sufficient ingenuity to carry it out in practice. He, however, submitted the notion to his friends, Messrs. Duckworth and Clegg, two engineers of the time, and although they were all three of opinion that the idea was capable of realisation, they found that the accomplishment of their object was so beset with difficulties that they eventually allowed the matter to drop. Taylor's scheme only extended to the conveyance of letters and despatches. He suggested that a tube, large enough to contain a parcel, should be laid down from one town to another, a stationary engine being employed at either end to exhaust the tube.

The subject was then taken up by Mr. George Medhurst, a London engineer, who, in 1810, published a pamphlet in which he described "A New Method of Conveying Goods and Letters by Air." Two years later he published his calculations and remarks on the practicability of his scheme. By the year 1827 Medhurst appears to have further developed his ideas, for in a pamphlet which he then published he describes a system in which he employed a tube through which he drove a carriage by air pressure in one direction and drew it by vacuum in the other. A further development of the system was the employment of a tube 24-in. in diameter, within which worked a piston with a piston-rod passing upward through a longitudinal channel and connected to a carriage running on rails. The piston was to be driven by air-pressure, and the channel was to have a water seal. His third suggestion was a combination of the two methods, goods being conveyed within the tube and passengers in a carriage outside it. Yet another method proposed by Medhurst was to have an iron air tube of square section, 4-ft. in area, fitted with a longitudinal flap valve on the top, through which the arm of the piston projected, and was attached to a carriage running upon the ordinary roadway without any rails. By this modification goods and passengers were to be conveyed "at the rate of a mile a minute, or sixty miles an hour, and without any obstruction, except at times contrary winds, which may retard its progress, and

heavy snow, which may obstruct it." However wild Mr. Medhurst's system may appear, to him must be given the credit of originating the longitudinal valve on the tube, a principle which underlies the inventions of nearly all others who subsequently sought to solve the problem of pneumatic propulsion with external carriages.

Previously to the appearance of Medhurst's last pamphlet, Mr. Vallance had, in 1824, taken out a patent for his system of locomotion by atmospheric pressure. This system was described by us in the article already referred to, so that we need not here do more than observe that it was only a modification of Medhurst's first suggestion of a tube through which a carriage was to be propelled and drawn alternately by means of a plenum and a vacuum. The working model of this railway, 150 ft. in length and 8 ft. in diameter, appears to have been the extent of the application of the principle by Mr. Vallance. In 1834 Mr. Henry Pinkus appeared upon the scene with a patent for a pneumatic railway, which was on the same principle as Medhurst's fourth modification, with the exception that Pinkus proposed to use a circular instead of a square tube, and to employ a hemp-and-tallow rope for his continuous valve. The rope valve was to be opened by a small friction roller passing under it, and closed by another passing over it, both being attached to the carriage about it. In practice, however, it was found that on employing a vacuum the rope was forced into the tube by the external pressure of the atmosphere, the vacuum being thus destroyed.

The question now was to devise a valve which should neither be blown out under internal, nor be forced in under external pressure. And here Mr. Clegg took up the running, and in 1839 obtained a patent for a continuous valve having a leather hinge, and working in a trough containing a fatty composition which was solid at the ordinary temperature, but which was easily melted by the application of warmth. This, of course, involved the heating of the composition in order to seal the valve in the rear of the opener as the carriage passed onward, and this was to be effected by a tubular heater containing burning charcoal. Besides the modification of the valve, Mr. Clegg, in conjunction with Mr. Samuda, improved the armature, which, instead of proceeding vertically from the piston to the carriage as in Pinkus' patent, passed through the valve at a very low angle—nearly horizontally, in fact—which caused the valve to be only very slightly opened. The details of the piston were also materially modified by the same inventors, whose names stand out very prominently in the history of the atmospheric railway.

So far the respective inventors only availed themselves mainly of the mechanical properties of the atmosphere resulting from its action on a piston working in a tube and connected, through a continuous valve, with an external carriage. In 1844 Mr. James Pilbrow pointed out that the idea did not appear to have occurred to anyone to connect a carriage outside the tube to a piston within it without the use of the continuous valve. He therefore patented a system which consisted of a circular tube having a longitudinal square chamber mounted on the top and opening into it. The piston, which travelled in the tube, was connected by an armature with a tail-piece which travelled in the square chamber above it. This tail-piece was a double rack, which, as it passed along, drove pinions fixed at intervals in pairs on either side of it. The spindles of these pinions were continued upward through stuffing-boxes, their upper ends carrying pinions gearing into racks attached to the underframing of the first carriage of the train. This system was designed for use either on common roads or on railways. Two other modifications of the continuous valve should have a passing notice. They are those of M. Hallette and Mr. Hay, the former of whom proposed to close the longitudinal aperture of the piston tube by means of two elastic tubes containing water under pressure, the armature of the piston passing between the tubes. Mr. Hay proposed to supersede the hinged valve by one which was free at both edges—a mere strip, in fact, held at the two extremities and passing through a forked armature.

Such are the broad and general principles upon which the construction of the old atmospheric railways were based. These principles were applied in practice to a limited extent only, although, in some instances, with considerable promise of success. In 1840, Messrs. Clegg and Samuda's system was laid down experimentally on a portion of the West Lon-

don Railway, at Wormwood Scrubbs. So favorable were the results, that the atmospheric system was adopted on the Dalkey extension of the Dublin and Kingstown Railway, and this—the first atmospheric railway—was in full operation at the commencement of 1844. Its satisfactory working is alluded to in the report of the House of Commons Select Committee, to which we have already referred. This success led to the London and Croydon Railway Company, in 1844, laying down a line of atmospheric railway alongside its locomotive line, and, further, to the adoption of this method of working by the South Devon Railway Company on a portion of its line. On the latter lines, however, the principle was soon given up as unsatisfactory. It was likewise ultimately abandoned on the Kingstown and Dalkey line after a trial of several years, when the railway was extended to Wicklow. The results of working in all cases clearly showed that the atmospheric system could not compete with the locomotive with any hope of success. The first cost was favorable, but the expense and extreme care necessary to keep the tube and its accessories in working order killed it. Thus, the history of atmospheric railways can only be considered as a chapter of failures.

Later times, however, have witnessed a return to the principle, but worked out under conditions differing widely from those under which it existed in the examples we have mentioned. In the pneumatic system, as it was now called in contradistinction to the old title of atmospheric, a tube of large diameter was employed, the carriage itself forming the piston, a useful vacuum being thus obtained. It was, in fact, Mr. Taylor's original proposition, which improved mechanical appliances enabled engineers to work out in practice. About thirty years since the pneumatic system was carried out in various ways. An experimental line of pneumatic despatch was laid down and worked at Battersea, whilst later on a shorter pneumatic passenger railway, embodying advances in detail, was constructed and worked for a time at the Crystal Palace. The outcome of the experimental working of these two lines was the construction of a pneumatic despatch tube by Mr. Ramell in the very heart of London. This tube extended from the General Postoffice, St. Martin's-le-Grand, to the London and Northwestern Railway terminus at Euston Square. There was a central station in Holborn, where was placed the machinery for effecting the transit of the trains of carriers. The air motor consisted of a 22-ft. fan, driven by a steam engine having a pair of 24-in. cylinders with a 20-in. stroke. The tube was of a flattened horseshoe section, 5 ft. wide and 4 ft. 6 in. high at the centre, and had a sectional area of 17 sq. ft. The tube between the General Postoffice and Holborn was 1,658 yds. in length, or nearly a mile, the length from Holborn to Euston being 3,080 yds., or a mile and three-quarters. The carriers, which were 10 ft. 4 in. in length, were at the ends of the same sectional area as the tube, and weighed 22 cwt. each. The trains of carriers were drawn from the postoffice and from Euston by exhaust, and were propelled to those points by pressure. Although the system worked very successfully, and was proved to be well adapted for the safe and rapid transit of mail bags and parcels, neither the postoffice authorities nor the general public availed themselves of its services, and this revival of the atmospheric principle proved a commercial failure, and the pneumatic despatch fell into desuetude. It was also proposed to work vehicles in the tunnel under the Thames between Smithfield and the south side by the pneumatic system, but nothing was done in this direction. So far as we are aware, the only form in which the principle has survived is that employed in connection with the telegraphic department of the General Postoffice.

It now only remains to refer briefly to the Select Committee of the House of Commons, which was appointed in 1845 to inquire into the merits of the atmospheric system, with a view to its general adoption. The committee consisted of the following members: Mr. Shaw, Mr. Bingham Baring, Lord Harry Vane, Sir George Clerk, Mr. Baring, Viscount Mahon, Sir Charles Lemon, Mr. Hawes, Viscount Hawick, Mr. Hodgson Hinde, Mr. Morrison, Mr. Pakington, Mr. Gibson Craig, Mr. Lascelles, and Mr. Wyse. The committee took ample scientific evidence, but it was of a very conflicting character. Among the witnesses in favor of the atmospheric system were some of the leading engineers of the day, including Brunel, Vignoles, Bidder, Samuda,

and Cubitt. On the other hand, there were the opinions of equally eminent engineers against it, including Stephenson, Locke and Nicholson, all of whom strenuously advocated the use of steam. The committee reported strongly in favor of the general merits of the atmospheric principle, but wisely recommended that it should be left to experience to determine under what conditions of traffic or of country the preference to either system should be given. Experience was not long in determining in favor of steam locomotion, the disciples of which system rapidly increased and multiplied exceedingly.—The Engineer.

Pneumatic Tools

The Chicago Pneumatic Tool Co. reports sales during the last week in July of thirteen hammers and drills to the New York Navy Yard, including one of their shell riveters for bottom riveting, and eighteen pneumatic tools for the Chinese Eastern Railway. The latter order included a duplex compressor, furnished by the Pneumatic Supply & Equipment Co., with receiver, hose, etc., to complete the installation.

The tools made by the Chicago Pneumatic Tool Co. are being adopted in Europe, and exhibitions are given to show what they can do.

Recently a trial of them was made at the shipyard of Messrs. Alexander Stephens & Sons, Linthouse, Scotland, under the auspices of Messrs. Taite, Howard & Co., represented by John Macdonald & Son of Glasgow, who were confident that a trial would convince Clyde builders of the usefulness of these tools.

The riveting appliances were shown for the first time in Britain, and were watched with considerable interest by a number of engineering experts, and who were generally satisfied that good work was done.

The Railroad Master Mechanics' Convention, held at Old Point Comfort, Va., in June last, is recalled by a handsome souvenir issued by the Chicago Pneumatic Tool Co. All of their products were exhibited there, and special edition No. 8 catalogue reproduces the scenes of the occasion, in addition to other interesting views.

The No. 5 Whitelaw Reversible Wood Boring Machine has been brought out as an improvement on the machines thus far produced to meet the demand for a high grade Reversible Boring Machine. This machine weighs less than 10 lbs., is compact in form, easy to handle so that it can be used in any position and will bore in wood up to three inches in diameter. It is built in the best mechanical shape with ball bearings throughout, and as it reverses with a quarter turn of the handle it is perfectly under the control of the operator and can be reversed while running at full speed, and operates with

equal facility backward or forward. The machine is very economical in the use of compressed air requiring only 8 to 12 cubic feet of free air per minute and has met with the highest favor everywhere, having been recently adopted by the Pennsylvania Railroad.

This is one of the new tools shown by the Chicago Pneumatic Tool Co. at the Master Mechanic Convention at Old Point Comfort in June, and with the other new tools brought out by them, together with the well-known Boyer and Haeseler tools which they control, places them in a most commanding position in the line of pneumatic appliances throughout the world.

Glove Cleaner.

A pressure of air gently inflates kid gloves, keeping them in form while soil is removed.

PATENTS GRANTED JULY, 1899.

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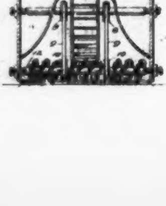
628,251.—Atomizer. Roland Morrill, Benton Harbor, Mich. Assignor of one-half to Fernando Morley, same place.

An atomizer in combination with a liquid reservoir, a liquid tube, an air nozzle having its discharge orifice disposed in proximity to the orifice of the liquid tube, and means for discharging air through said nozzle, of a disk disposed in the nozzle, some distance in rear of the discharge orifice, said disk having a radial slit and having a portion thereof adjacent to the slit deflected to form a passage for the air, substantially as set forth.

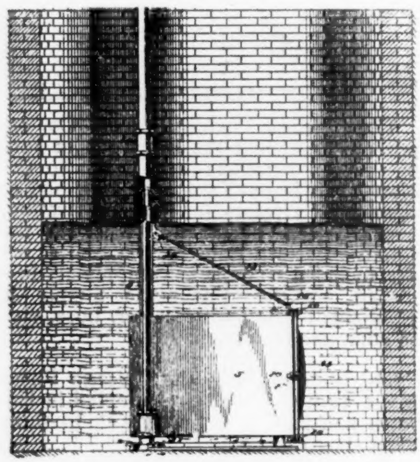
628,505.—Pneumatic Carpet-Sweeper. George L. Westman, Richmond, Va. Filed Nov. 5, 1898. Serial No. 695,597. (No model.)

In a carpet dusting device, the combination with a normally stationary exhaust pan and a portable duster box connected thereto by a flexible suction pipe, of a suction fan mounted in said box in the path of the air-current, and a rotary brush mounted in said box and operatively connected to said suction fan, substantially as shown and described.



628,318.—Compressed Air Water Elevator. Fred Hayes, Bristol, Tenn., and Horace L. Frost, Bristol, Va.

In a compressed air water elevator, the air pressure pipe and the liquid ejection pipe having the coincident non-revoluble tubular journals, and a rocking tank mounted eccentrically and loosely on said journals to turn freely thereon, the journal of the eduction pipe communicating directly with the chamber of said tank, combined with a liquid induction valve at the free or unconfined end of said tank, a branch air pipe contained within the tank to extend above the liquid level therein, and an air pressure valve mounted on the air pressure pipe, and connected with said tank to be opened and closed thereby as the tank is rocked on the journals.

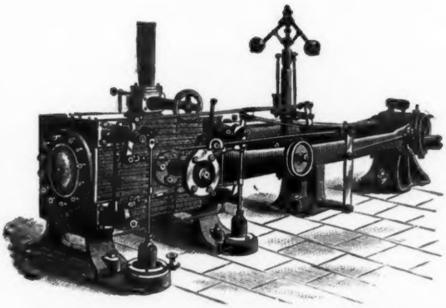


629,657.—Air Brake Hose Coupling. James Caldwell, Wooddale, Pa. Assignor of one-half to Norman W. Hemminger, same place.

An air brake coupling comprising two interlocking coupler heads capable of longitudinal movement on each other, and the transversely swinging link mounted on one of the coupler heads and adapted to be swung into and out of engagement with the other coupler head.

629,708.—Air Brake. Ellis Bartholomew, Lima, Ohio.

An air brake, in combination with a compressor having a governor connected thereto and a brake cylinder, of a valve seat having a plurality of ports therein, a discharge pipe and a suction pipe leading from the air compressor to said seat, pipes connecting the seat and brake cylinder, and a rotatable valve on said seat having cavities therein and adapted to establish communication between said ports.



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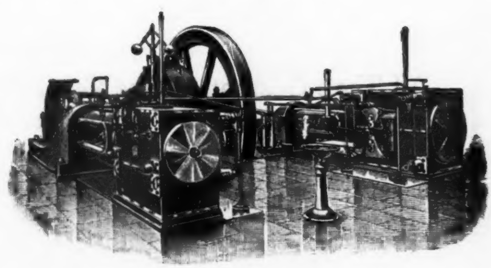

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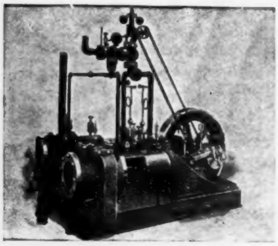

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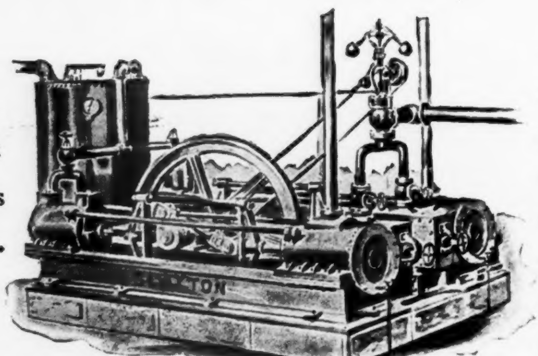

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